Exam preparation

Energy supply, economics & transition

A short note on the examen

- Date, time and location to be announced
- 2 hours written exam, no material allowed, except a memento sheet prepared by the teachers, which will be distributed during the exam
- Use of non-programmable calculator
- You need a sound understanding and feeling for what was discussed and presented in the lecture, but no need to remember all details such as precise specific data (but you should remember orders of magnitude)
- Questions in multiple-choice format; one correct answer per question; points given for correct choice and taken away for wrong choice; 0 point for no answer

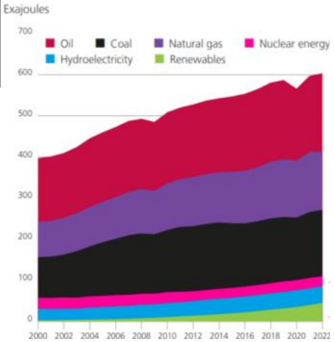
Memento sheet (to be updated)

Memento

Conversions

- 1kWh = 1000 W x 1 h = 3’600’000 J
- 1 Barrel of oil ≃ 159 liters of oil
- 1 BOE ≃ 6.1 GJ ≃ 1.7 MWh
- 1 TOE ≃ 41.9 GJ ≃ 11’630 kWh
- 1 BTU ≃ 1055 J ≃ 0.293 Wh
- Energy of 1 liter of oil ≃ Energy of 1m^3 of natural gas ≃ 11 kWh. Energy of 1kg of coal ≃ 8 kWh
- Burning 1 liter of oil → 2.3 kg of CO2. Burning 1m^3 of gas → 1.9 kg CO2. Burning 1kg of coal→ 2.6 kg of CO2.

World Energy consumption (ExaJoules)



Some orders of magnitude:

- Annual solar energy reaching earth’s surface: 1’485’000 PWh = 5.346 · 10^{24} J
- World population today: 8.1 billion people, including 4.8 billion Asian
- World annual primary energy consumption: 168 PWh or 168’000 TWh, or 605 EJ.
- World current yearly CO2 emission mass: 41 GT (Gigatons), and 56 GT with CO2equivalent
- Daily world oil demand: 100 million barrels or 160 TWh
- Per capita power consumption (permanent): from 100 Watt (Burundi) to > 10’000 W (e.g. USA, UAE)
- Per capita annual CO2 emission: 5 to 15 tons for industrialized countries
- CO2 emission for transport, heating and electricity generation: 70% of total CO2 emission
- Swiss Per capita annual CO2 emission: 4.5 tons (Production based), 14 tons (consumption based)
- Swiss annual electricity consumption: 60 TWh, ~ 25% of the final consumption (rest mostly fossil)
- Efficiency of nuclear, coal, oil power plants: Typical ~ 30-33%, supercritical coal 40-45% (rare)
- Gas power plant efficiency: ~40-45% up to 60% for CC power plant (rare)
- Other emissions “equivalent CO2”: ~11-15 GT (Methane + Nitrous oxides + other gases)
- Price of oil in 2024: ≃ 60-80 $ / barrel
- Typical EU market gas price 2024: 30-40 $/MWh

- Typical coal price 2024: 90-120 $/ton
- Typical marginal kWh cost of burning coal: 3-4 cts/kWh without CO2 tax
- LCOE of large solar or wind parks: 2-5 cts/kWh (n.b. offshore wind costs more)
- LCOE of electricity from new fossil plants: 5-10 cts/kWh (estimates) without CO2 taxes
- Car Battery pack cost in 2024: ~100-120 $/kWh
- New Renewable electricity (outside hydro) produced in 2023: 4’700 TWh (2’304 wind, 1’629 solar, 767 other), around 10% of total electricity production (0 TWh in 1995). (data from chart Electricity production by source, World (ourworldindata.org))
- Typical good CO2 emission per capacity: 200gCO2/W for wind turbines, 300g CO2/W for solar panels

Definitions

- LCOE: The average net present cost of energy (electricity) generation for a generating plant over its lifetime (including construction, maintenance, operation, interest etc.). Calculated in $Price$/Energy.
- In BP reports, the electricity production from renewables translates into primary energy consumption multiplied by a factor of 1/0.41 (substitution method). This results in primary energy consumption showing over 80% fossil fuels share, including 27% coal.
- The Swiss energy statistics based on IEA or on the Swiss Federal office for energy apply a factor of 1/0.33 for Primary Nuclear energy and of 1 for non-thermal renewable sources (e.g. Hydro, wind, solar).
- The temperature around the globe since civilization development varied of ± 0.5°C until 1900. Nowadays, business as usual scenarios lead to a rise of +3.5 to +7°C in temperature by the end of the century. With current emission rate, we have roughly 5 years left for the 1.5°C scenarios (which for some is already present), and 20 years for the 2° scenarios..

Example Part 1 (Ballif)

- Which fraction of greenhouse gas emission is linked to the burning of fossil fuel and CO2 emission

❑ 54 %
❑ 82%
❑ 98 %

- How many years can we still emit greenhouses gases the way we do in a 2°C temperature increase scenario

❑ 50 years
❑ 20 years
❑ 10 years
❑ 7 years

- Assuming you set-up a

1 GW of solar (Capex 0.5€, capacity factor 17%), 0.5 GW wind (Capex 2€/W, capacity factor 27%), and that you need 5 GWh of batteries to fully dispatch your electricity (Capex 300$/kWh).

Assuming 0%, cost of capital and a duration of 20 years, what would be your average cost of electricity ?

❑ 2.7 €cts/kWh
❑ 7.1 €cts/kWh
❑ 12.5 €cts/kWh
❑ 5.4 € cts/kWh
❑ 21.3 cts/kWh
❑ 71 €/MWh

Which would be the typical estimated cost of direct CO2 sequestration from large coal powerplants and how much would it add to cost of electricity?

❑ 10-20 €/ton of CO2 and add 2 to 4 cts/kWh
❑ 20-30 €/ton of CO2 and add 2-3 cts/kWh
❑ 80-110 €/ton of CO2 and add 8-10 cts/kWh
❑ 80-110 €/ton of CO2 and add 4-6 cts/kWh

Example Part 2 (Thalmann & Nick)

The following data describe the evolution of some key variables in some country over the last 10 years (cumulated): GDP increased by 10%, population increased by 5%, energy use per capita decreased by 3%. How can we characterize the decoupling between economic growth and energy use in this country over the last 10 years?

You get 1 point if you tick the correct answer and only the correct answer, 0 point if you tick no answer, −1 point if you tick a wrong answer or more than one answer

☐ Absolute decoupling.

☐ Relative decoupling.

☐ No decoupling at all.

☐ We cannot say, we do not have enough data.

Example Part 2 (Thalmann & Nick)

Which of the following statement(s) is/are true in the sense that they correspond to the economic principles seen in class?

For each statement, you get 1/2 point if you tick the correct answer and only the correct answer, 0 point if you tick no answer, −1/2 point if you tick a wrong answer or more than one answer

	TRUE	FALSE
Public policies that allow energy investors to obtain financing at lower financial cost lower their hurdle rate and, thus, induce more investment		
Public policies that allow energy investors to earn higher internal rates of return on their investments will allow more projects to pass the hurdle rate and, thus, induce more investment		
Public policies that set requirements on energy investment for environmental reasons raise the hurdle rate for such investment		
Public policies that take on some of the risks of energy investment lower the hurdle rate for energy investors and, thus, induce more investment		

Example Part 3 (HERUS team)

In the context of the Multi-Level Perspective (MLP) on transitions, what role do "niches" play within the framework? "Niches" are best described as:

☐ Representing the broader societal and environmental patterns that can impact or pressure existing regimes.

☐ Locked-in systems that resist significant changes and prefer gradual improvements.

☐ Alternatives to dominant practices, with potential to drive regime change, often referred to as proto regimes.

☐ Providing the established technological frameworks that support current economic and social systems.

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